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MULTIPLE PULSES OF AQUEOUS SOLUTIONS IN QUE 93005 (CM2): EVIDENCE FROM OXYGEN ISOTOPES.

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Introduction: Aqueous alteration of CM carbonaceous chondrite parent bodies early in the solar system history produced secondary minerals including carbonates [1-2]. These carbonates provide snapshots of the reactive fluids so that their oxygen isotope compositions contain important information on solution provenance and temperature [3-5]. Previous analysis of bulk samples showed that calcite $\delta^{18}\text{O}$ and $\Delta^{17}\text{O}$ values differ between CMs [6] and recent ion microprobe work has revealed that the oxygen isotope ratios also vary substantially within individual meteorites. This intra-CM variation may be due to mineralization during a secular change in fluid composition [5,6] or temperature [7,8], or to the presence of clasts [5]. To understand better the significance of variations in carbonate oxygen isotope compositions within CMs, we have studied the highly aqueously altered QUE 93005 (CM2.1), which contains three petrographically distinct types of calcite [9].

Methods: Carbonate grains were studied via BSE/SE imaging and ED X-ray analyses using a Zeiss Sigma FEG-SEM operated at 20kV. Selected grains were analysed using a NanoSIMS 50L at the Open University (UK). Analyses were performed in spot mode and with a ~50pA Cs⁺ ion beam; ¹⁶O was measured on a Faraday cup and ¹⁷O and ¹⁸O using electron multipliers.

Results and discussion: QUE 93005 contains three petrographic types of calcite; (i) equant grains in the matrix that sometimes host coarse subhedral Fe(Ni)-sulphides, (ii) multi-mineralic grains containing calcite along with dolomite and in some cases also breunnerite [9], (iii) irregular grains rich in micropores and μm -sized sulphide inclusions. The temporal relationships between calcite in the equant grains and the multi-mineralic grains is unclear from petrographic observations, while the porous irregular calcite is inferred to be late-stage, forming as a replacement product of chondrules similar to calcite described by [7,8]. NanoSIMS results are consistent with the micropore-rich replacive calcite being late ($\delta^{18}\text{O}$ 14.79 ± 0.64 (2 σ) ‰, $\Delta^{17}\text{O}$ -0.39 ± 1.52 (2 σ) ‰) while calcite in the multi-mineralic grains may have crystallized first (two grains at $\delta^{18}\text{O}$ 38.68 ± 1.19 (2 σ) ‰, $\Delta^{17}\text{O}$ 0.02 ± 1.84 (2 σ) ‰ and $\delta^{18}\text{O}$ 29.91 ± 1.19 (2 σ) ‰, $\Delta^{17}\text{O}$ 0.39 ± 1.84 (2 σ) ‰). The equant grains, on the other hand, span a wider range of values. Whilst the temporal relationships between these calcite types need clarifying, the data suggest that different petrographic types of calcite formed from discrete pulses of aqueous solutions.

References: [1] McSween H.Y. 1979. *GCA* 43:1761-1770 [2] Bunch T.E. & Chang S. 1980. *GCA* 44: 1543-1577 [3] Guo W. & Eiler J.M. 2007. *GCA* 71:5565-5575 [4] Clayton R.N. & Mayeda T.K. 1984. *EPSL* 67:151-161 [5] Horstmann M. 2014. *45th LPSC* #1761 [6] Benedix G. K. et al. 2003. *GCA* 67:1577-1588 [7] Tyra M.A. et al. 2012. *GCA* 77:383-395 [8] Lee M.R. et al. 2013. *GCA* 121:452-466 [9] Lee M.R. et al. 2012. *GCA* 92:148-169. **Acknowledgements:** NASA AntMet, UKCAN